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ABSTRACT

Drawing from literature on technological advances, economic trends, and employment and labor market projections, this paper provides an overview of trends and their implications for California. After briefly analyzing the characteristics and effects of the information age, the paper examines the growth and development of high technology industries; emerging technologies with immediate or near-term applications; the commercialization of new technologies; and the role of science and technology in economic development. The next section looks at employment trends, highlighting the effects of increasing global interdependence, workforce projections, and regional variation. Summary comments project the following: (1) developing technology will affect how work is performed but contribute little to total job growth; (2) overall income distribution is likely to flatten in the middle range and rise in high and low ranges; (3) economic change will occur rapidly, but unevenly, resulting in frequent worker displacement, and business starts and failures; (4) growth of high technology industries will be related to commercialization of products, with information processing technology growing faster than alternative energy or biochemical technology; (5) American and California output will largely depend on advantageous technical development, improved educational and training systems, increased productivity, and commercial diversity; and (6) global interdependence will continue to affect trade balances, monetary values, employment, and wages. (LAL)

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TRENDS IN TECHNOLOGY AND EMPLOYMENT

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TRENDS IN TECHNOLOGY AND EMPLOYMENT

The Information Age

Today more than 60 percent of American workers have information jobs--as programmers, teachers, clerks, secretaries, accountants, stock brokers, managers, insurance adjusters and realtors, lawyers, bankers, researchers and technicians (1). Only 13 percent of the labor force is engaged in manufacturing (2). Today's information-based economy relies on the use of information technologies to automate mental processes much like yesterday's industrial economy depended on machines to reduce physical labor. The revolution in work functions today will be no less dramatic than the shift from an agricultural to an industrial economy early in this century. Change will rely primarily on technological development and will occur unevenly, benefitting some but not others (3). Understanding the scope and direction of developing technology will be critical to maintaining social and economic vitality.

High Technology

Measuring the growth and development of high technology industries has lacked precise definition, but most analysts employ the following criteria: research and development expenditures, use of scientific and technical personnel relative to total employment, and product sophistication. Using all these criteria, a research group within the Bureau of Labor Statistics identified the following growth industries (4):

Industries	Growth from 1972-1982
Computer and data processing services	+ 235.1%
Office, computing and accounting machines	+ 88.6
Optical instruments and lenses	+ 84.7
Surgical, medical and dental instruments	+ 77.2
Electronic components and accessories	+ 60.3
Measuring and controlling instruments	+ 53.1
Research and development laboratories	+ 47.0
Guided missile and space vehicles	+ 37.5
Drugs	+ 25.5
Industrial organic chemicals	+ 22.1
Communication equipment	+ 21.2
Agricultural chemicals	+ 19.0
Soaps, cleaners and toilet preparations	+ 18.7
Photographic equipment and supplies	+ 18.1
Engineering, laboratory, scientific and research instruments	+ 17.4
Petroleum refining	+ 11.6
Industrial inorganic chemicals	+ 8.7

Emerging technologies are likely to progress in scope from those which lend themselves to the greatest commercialization, such as information processing, to scientific breakthroughs such as those related to biotechnology. While information processing and transmission primarily rely on the physical

sciences related to electronics and electro-magnetics, new developments will increasingly incorporate biological and chemical hybrid technology. These developments will affect new energy sources and applications, and new materials and processes which will profoundly change patterns of work and production.

The staging of developments with the greatest impact on work and other commercial applications will most likely follow a progression from information processing to new energy sources and then to biochemical technologies, which will utilize and interface with information and energy technology. In the next twenty to forty years, new developments in energy and biochemical technology may affect work roles and incentives as much as the revolution in information technology.

A 1982 study by the Stanford Research Institute (SRI) has identified seven emerging technological groups: Computer Science, Electronics, Electro-Optics, Energy, Biological Engineering, Materials and Miscellaneous (5). These may be collapsed into the progressive sequence noted above:

> information processing, including computer science, electronics and electro-optics;
>
> energy alternatives, including new or recombined sources and new methods of storage and transmission; and
>
> biochemical technology, including biological engineering, the development of new processes or materials, and the introduction of hybrid processes which may include physics.

The SRI study not only identified emerging technologies, but immediate and potential applications. In the listing below, grouped under the three categories noted above, those technologies affecting California in the 1980s are distinguished by an asterisk (*).

Immediate or Near-Term Application	Emerging Technological Development
Information Processing:	
Electronic media*	Optical computers
Broadband communication*	High-level language
Computer-Aided Design (CAD)*	Speech synthesis, recognition and understanding
Industrial robots*	Logic arrays
Factory automation	Packet switching
Optical disks*	Josephson junctions
Artificial intelligence and expect systems*	VLSI lithography
Microwave	Bubble memory
Lasers and laser semiconductors	Transponders
Fiber optics	Crogenic superconductors
Silicon foundries	Gallium arsenide
Fault tolerant chips	Earth stations
Satellites	

Immediate or Near-Term Application	Emerging Technological Development
Alternative Energy:	
Heat pumps*	Solar hot water
Photovoltaics*	Synfuels (methanol, ethenol)
Cogeneration	Geothermal energy sources
Energy management/control systems*	Fuel cells, batteries
Wind generation	Solid electrolytes
Oil recovery	Ultrasound
New fuels (e.g., carbon combinents)	Controlled atmoshperes
Small hydro-eiecdtric plants	Pressure vessels
Fusion reactors	Hybrid nuclear fusion
	Advanced fission
Biochemical Technology:	
Recombinant DNA (with applications for insulin and interferon treatment and for gene therapy)*	Hybridoma
	Enzymes
	Growth hormones/vaccines
Tissue culture/micropropagation*	Food supplements
Metallic glasses	Embryo transplants
High-temperature structural ceramics*	Aqua culture and other soil-free cultures
Biocatalysts	Ocean mining
Fine chemicals	Polymers
Filtration	Thin films and membrance technologies
Extraction of contaminants	
Pharmaceuticals	Metal matrix and brazing alloys
Testing: diagnostic, validity, non-invasive; CAT scanners	Supercritical fluids
	Fermentation
Microsurgery	
Treatment therapies	
Implants	

A more simplified template of future development, resulting from an analysis by the Department of Economic and Business Development in 1982, identified the following emerging technologies--many with commercial potential (6):

- More powerful computers, broadband communication via satellite, fiber optics, coaxial cable and millimeter waves, new electronic media for broadcasting, education, entertainment, retailing and professional knowledge; optical discs.
- Industrial robots; computer-aided design; sensors that translate physical stimuli into electronic signals; artificial, problem-solving intelligence.
- More efficient heat pumps; photovoltaics; cogeneration; energy management and control systems.

- Bio-engineering with recombinant DNA; preservation of agricultural produce by irradiation; tissue culture micropropagation.

- Solid electrolytes for sensors and more efficient batteries; high-temperature, structural ceramics and metallic glasses.

The projections are consistent with the trends indicated by the SRI study, and generally follow the sequence of commercial development from information processing to biochemical technology discussed above. Industrial growth in these areas, however, will depend on adequate research and development and the availability of technicians with both theoretical knowledge and practical experience.

Commercialization of information processing has been possible because of increasing miniaturation and portability ("lap" computers), low-energy transmission, integrated systems (satellite relays, telecommunications) and user-friendly software. In 1984 there were more than 180 personal computer companies, most of them non-existent five years ago (7). In 1984 Americans are expected to spend $65 billion on computers of all kinds and an additional $16.2 billion on software (8). At least 1,000 companies are making software programs, and a Whole Earth Software Catalog will be published in Fall 1984. Sales in 1984 of software for personal computers is expected to reach $1.5 billion, up from $260 million in 1980. The most popular programs are for text-editing or word processing, followed by those for business uses (e.g. accounting), entertainment and education.

Growth in the commercialization of alternate energy sources has been supressed by the so-called "oil glut" and "gas bubble" phenomena, supplying sufficient quantities of traditional fuels at costs that are not prohibitive. The cost of a barrel of oil, in constant dollars, was $7.82 in 1979, $12.75 in 1980, and $10.94 in 1982 (9). Higher energy costs have also restrained consumption; buildings are being retrofitted with energy-efficient heating and lighting systems with monitors, and large cars are being replaced with smaller, gas efficient models. American consumption of BTUs fell from 76.332 quadrillion in 1977 to 73.895 quadrillion in 1981 (10).

In a 1982 study by Data Resources Incorporated, consumption of gas and oil are projected to decrease from 41 percent to 23 percent during 1980-2000, while use of coal products is expected to increase from 19 percent to 36 percent (11). Although nuclear power consumption is projected to increase from 3 percent to 7 percent, public resistance may intervene to actually reduce use of nuclear power. Reliance on domestic sources is expected to increase from 78 percent to 93 percent.

Short-term energy-related technological growth may well be in the storage and transmission of energy rather than in the development of alternative sources. An exception appears to be the commercialization of photovoltaic sources, an industry with growth potential particularly strong in the Southwest.

Commercialization of biochemical technologies will be most rapid for agricultural, medical and pharmaceutical applications. Medical applications which involve ethnics or interference with "natural" processes will be developed cautiously.

The role that science and technology will play in providing new economic potential is unquestionable. The 1982 Report of the California Commission on Industrial Innovation (12) states that:

> --we must look to a new, "post-industrial" economy built around relatively resource-efficient information technologies and innovation.
>
> In this new economy, promoting innovation for new growth industries, and modernization for older ones, must become the driving imperative of our economic thinking. New growth industries are defined here as producers of innovation, such as computers, robotics and biotechnology.
>
> Clearly, these industries' success in developing innovative products can have a major positive effect on present industries such as textiles, autos and agriculture, classified as users of innovation. In fact, continued technological innovation is the only long-term solution for today's manufacturing industries facing international competition. Therefore, an industrial strategy for California and the nation must incorporate measures which facilitate the adoption of new technologies by mature industries as well as encourage their production.

The nation has been sobered by recent high inflation and unemployment, and a severe recession. While recovery has been strong, the national debt continues to soar while imports far exceed exports. Will American leadership in technological development restore American economic growth and stability? The answer is an elusive one, but technological innovation logically progresses from post-industrial conditions. The following section looks at employment trends in an emerging "information-based economy" (13).

Employment Trends

Global interdependence. Standardized, American mass production created great wealth which peaked about 1965. Strong unions drove wages up, enabling American workers to purchase American-made products and to enjoy unparalleled prosperity. Between 1965 and 1981, real income for American workers declined 20 percent (14). Union membership dropped from 32 percent to 28 percent of the nation's non-agricultural workforce. Recent United Auto Worker (UAW) negotiations tell the story: demands were greater for job security than for wage increases (15).

Trade balances were of little importance to the United Stataes when only a small proportion of manufactured goods were imported or exported. By 1981, imports were growing proportions of American sales: 26 percent for cars, 17 percent for steel, 60 percent for televisions, radios, tape recorders and phonographs, 43 percent for computerized machine tools; in 1961, less than 10 percent of these product sales were for imported goods (16).

Competition from "newly industrialized countries" (NICs) has emerged in the last twenty years and has recently escalated. Contributing factors include (17):

1. the export of new technologies and manufacturing processes, with automated devices facilitating the use of unskilled or semi-skilled workers;

2. the availability of locally-produced raw materials, acquired at much lower costs than American manufacturers must pay;

3. national NIC policies which encourage capital investment in manufacturing industries; and

4. much lower labor costs than in the United States.

The pattern works like this: poor countries with little development and few skilled workers concentrate on industries such as textiles with simple production requirements. With the creation of an economic base, manufacturing expands to electronic components, automobiles and steel. Now competing with Japan in the Far East are the Little Dragon countries--Taiwan, Singapore, Hong Kong and South Korea. American competitors also include Brazil, Mexico and Spain.

Low-cost labor is an extremely important aspect of international competition, and it is a condition which changes rapidly. As countries improve their economic base, wages rise and new industries face competition from countries with lower labor costs. For example, in 1962 Japan was classified as a developing country, with exports primarily in textiles and apparel. Now automobiles are the largest proportion of Japanese exports, but manufacturing is increasingly concentrated in video cassette recorders, aircraft engines and computers--a deliberate move into high technology. Taiwan, forced out of shoes and textiles by lower-cost competition, in increasing its capacity for manufacturing computers and telecommunications equipment (18).

In 1983, American exports fell $11 billion while imports rose $15 billion, resulting in a $26 billion deficit and an estimated loss of 650,000 potential American jobs (19). Competition from NICs is not the only factor contributing to this trade deficit; others include 1) the robust value of the dollar, boosting prices for American goods overseas; 2) recovery from recession that has been slower in most foreign countries than in the United States, reducing demand for American exports; and 3) foreign debt, particularly in Latin American countries, which forces debt service expenditures in lieu of American export purchases.

These conditions are likely to affect policies related to protectionism, immigration, offshore manufacturing and foreign debt servicing. In general, however, global interdependence is here to stay, with developments changing rapidly and the production of many goods dependent on the use of components manufactured at offshore sites.

This new arena for competition will affect not only what American companies produce, but how they produce it. While technological innovation appears to be an American export advantage, the life of such products may be woefully short as they are duplicated or pirated by other production-efficient countries. Increased productivity in American through automation or robotization may further reduce job stability. Moreover, innovative technology requires highly trained researchers, professionals and technicians. Worker shortages remain for engineers, electronic specialists and computer programmers, machinists and industrial technicians (20). Many new jobs, such as technicians for robotics, laser, waste, energy or genetic engineering technologies will be created, with specialized training necessary (21).

Workforce projections. Near-term projections, from 1981 to 1991, have been made for California and the nation by the Center for Continuing Study of the California Economy. In their 1984 report, California economic and population growth is projected to exceed national averages (22). State projections were revised upward from 1982 estimates, made during a deepening recession. Principal factrors in job analyses were 1) an increasing focus on high technology jobs within the manufacturing sector nationwide, 2) a continuation of California's competitive advantage for the location of high technology jobs, 3) growth in defence and other aerospace jobs in the nation and state and 4) the competitive advantage of California as a location in the 1980s for non-high technology diversified manufacturing sector jobs. The Center projects that total jobs and the total labor force in California between 1980 and 1991 will increase at approximately the same rate, 25 percent, with increases in younger and older populations compensated for by decreases in working-age (16-64) populations.

Growth in California high-technology jobs was predicted by the California Employment Development Department, in cooperation with the Center for Continuing Study of the California Economy. Percentage increases from 1980 to 1990 were forecast for the following industries (23):

Industries	Percentage Increases
Computers	68
Communication equipment	26
Electronic components	20
Instruments	26
Computer services	196
Total	48

While these growth projections seem optomistic, they are based on relatively small numbers of employees. Major growth in job opportunities will continue to be in non-technological, service occupations. A 1983 Business Week article points out that high tech will exceed the growth output of other industries, but because the high tech sector is small and its productivity is also growing fast, it will create only a modest number of new jobs, with average annual increases in non-farm employment 2.1 percent from 1983 to 1988 and 1.2 percent from 1988 to 1993 (24).

This phenomenon can be illustrated by looking at the fastest-growing jobs between 1982 and 1995, as projected by the United States Bureau of Labor Statistics (25):

Occupation	Change in Total Employment (in thousands)	Percent of Total Job Growth	Percent Change
Building custodians	779	3.0	27.5
Cashiers	744	2.9	47.4
Secretaries	719	2.8	29.5
General Office Clerks	696	2.7	29.6
Salesclerks	685	2.7	23.5
Nurses, registered	642	2.5	48.9
Waiters, waitresses	562	2.2	33.8
Teachers, kindergarten/elementary	511	2.0	37.4
Truckdrivers	425	1.7	26.5
Nursing aides and orderlies	423	1.7	34.8
Sales representatives (technical)	386	1.5	29.3
Accountants and auditors	344	1.3	40.2
Automotive mechanics	324	1.3	38.3
Supervisors (of blue-collar workers)	319	1.2	26.6
Kitchen helpers	305	1.2	35.9
Guards and doorkeepers	300	1.2	47.3
Food preparation and service workers	297	1.2	36.7
Managers, store	292	1.1	30.1
Carpenters	247	1.0	28.6
Electrical and electroni technicians	222	.9	60.7
Licensed practical nurses	220	.9	37.1
Computer systems analysts	217	.8	85.3
Electrical engineers	209	.8	65.3
Computer programmers	205	.8	76.9
Maintenance repairers (utility)	193	.8	27.8
Helpers (trades)	190	.7	31.2
Receptionists	189	.7	48.8
Physicians	163	.7	31.8
Supervisors (of clerical workers)	162	.6	34.6
Computer operators	160	.6	75.8
Sales representatives (nontechnical)	160	.6	27.4
Lawyers	159	.6	34.3
Stock Clerks	156	.6	18.8
Typists	155	.6	15.7
Delivery and route workers	153	.6	19.2
Bookkeepers	152	.6	15.9
Bank Tellers	142	.6	30.0
Cooks (short order/specialty/ fast food)	141	.6	32.2

Note: these projections are based on moderate-trend forecasts and may favor long-term trends relying on historical patterns rather than short-term indicators of new growth or decline. For example, bank tellers, stock clerks, salesclerks and secretaries may not grow as expected because of automation; nursing professions may grow more slowly because of reduced medical subsidies.

Much of the job growth includes few opportunities for upward mobility. Many jobs will not be in technical industries, but in service occupations requiring little postsecondary skill development.

High technology may have other consequences that negatively affect egalitarian ideals. Stanford's Institute for Research on Educational Finance and Governance foresees that employment trends will lead to a growing dichotomy between a highly educated elite and a much larger mass at the lower end of the socio-economic scale--a bimodal distribution in contrast to the normal curve which has characterized American income dispersion (26). Use of automation is likely to "deskill" many jobs. In a study by Schement, et al, observations lead to the conclusion that (27):

> The emphasis on productivity in information splits the information workforce in two. On one side are the highly educated, highly paid creative professionals allowed to work according to their personal lifestyles. On the other side are those who omay carry out repetitive, fragmented tasks, under rigid supervision and control. Unlike traditional paths in other industries where workers might advance from the shop floor into management, the two information groups are almost completely separate--bimodal.

Other analysts, such as Frank Newman, project a different outlook (28):

> --the economy is both deskilling and skilling jobs at the same time as the complicated impact of a broad range of technologies take hold.

While the effects of technological innovation are expected to be profound, the near- and far-term implications for social and economic change are uncertain. While futurists project space stations and space travel, telecommutation to replace worksite commuting limitations, instant and diverse electronic communication, these developments may be restricted to a relatively small elite.

The Center for Continuing Study of the California Economy projects that overall production will show gains from the slowdown occuring since 1973. Two alternative projections are based on different assumptions regarding production gains in California; the high projection projects a gain of 2.1 percent annually during the decade 1981-1991, with the low projection a 1.4 percent annual increase (29).

High projections are based on the following assumptions:

- A slow rate of growth in energy prices.
- Increases in investment in plant and equipment, resulting from tax incentives and a reduced inflation rate.
- Increases in average training levels in the labor force, resulting from the assimilation of substantial increases in the labor force during the 1970s, which will have 10 years experience in the 1980s, and a decrease in labor force growth in the 15-24 age group.

- A slight increase in California's per capital income relative to the nation's.

The "maturing" of the workforce has several implications. On the one hand, the "experience curve" will rise, increasing productivity. On the other, technological innovation will require the retraining of existing workforce members to a degree equal to if not greater than the training of entering workforce members. Retraining and upgrading employment training programs will differ markedly from entry-level programs, with short-cycle, after-work or released-time programs contrasting with full-time, day-time modes of instruction.

Pat Choate, in a report titled Retooling the American Work Force, stresses the need to gear up for competitive workforce strength by supporting basic skills, retraining and service programs for American workers (30). Choate documents the need for "retooling by citing the following statistics:

- Twenty percent of American adults are functionally illiterate.
- Nearly 6 percent of the civilian workforce suffers from alcoholism.
- Two-thirds of American workers throughout the 1980s will be women, yet no sector of the economy effectively integrates them.
- Some occupations, such as machinists, have age norms approaching retirement, with replacement training programs inadequate to meet demands. A shortage of 240,000 machinists is projected by 1985.
- Displacement of workers through robotization and foreign production will affect 10 to 15 million manufacturing employees and a similar number of service workers, yet no coherent policy or program for retraining has been developed.

These and other similar recommendations have had on effect on the recent creation of retraining programs such as the Job Training Partnership Act (JTPA) at the national level and state support for employment training programs.

Increased productivity will make American industries more competitive, although jobs will be lost and increasingly white-collar or tin-collar rather than blue-collar. Productivity can increase by raising the skill levels of the workforce through training, education and experience; capital investment in research, development and equipment; and improved planning and management (31). These increases are more likely to occur in manufacturing, transactional (banking, real estate), communication and high technology industries than in service occupations which relay on personal interaction and judgment.

Global interdependence, changes in the composition of the workforce and in the means of production, capital investment and productivity all have an effect on employment projections. Strategic planning, whether at the company, state or national level, will need to continuously monitor trends while formulating intervention or development programs.

Regional variation. The promotion of innovative, high technology industries is attractive not only because they are "cleaner" than the smokestack industries of the industrial era, but because they rely on the highly skilled leadership of professionals and technicians. A vast system of American educational institutions, and a living standard in America that attracts talent from other countries, provides a pool of able leaders that is perhaps unparalleled.

Living standards and educational resources weigh heavily in decisions regarding industry location. The population shift from frost-belt to sun-belt areas is one example of the drive for location amenities. Another is the concentration of high technology industries in areas served by major universities. The Silicon Valley development drew upon resources from Stanford and Berkeley; Route 128 high-tech industries benefitted from the ivy-league institutions of the Northeast; universities in North Carolina contributed to the development of industries in the Research Triangle. There are smaller concentrations of high-tech industries in Austin, Denver, Ann Arbor and Philadelphia that utilize the resources of nearby universities (32).

Projections for California reflect these patterns. The Center for Continuing Study of the California Economy projects that all economic regions of California will grow faster than the nation in the 1980s, and that more than two-thirds of job growth will occur in the Los Angeles Basin and San Francisco areas (33).

The effects of technological development will be felt unevenly among states, cities, towns and neighborhoods. Competition is likely to increase for the attraction of high technology industries. In addition to living standards and amenities, and the availability of an educated workfdorce, tax advantages and regulatory differentials will influence location decisions.

Summary

Developing technology will have a major effect on how work is performed but contribute little to total job growth. With automation deskilling some job functions and skilling others, overall income distribution is likely to flatten in the middle range and rise in high and low ranges. Change will occur rapidly but unevenly, resulting in frequent displacement of workers, business starts and failures.

Growth of high technology industries will be related to the commercialization of products, with information processing technology growing faster than alternative energy or biochemical technology. Competition for computer-related products will increasingly involve price, portability, flexibility, integrated systems, speed and user ease.

Maintaining and increasing American and California output will largely depend on advantageous technical development, improved educational and training systems, increased productivity, and industrial and commercial diversity.

California is particularly well situated to attract growth industries and to support a broad range of industries and occupations. Job growth and productivity increases in California are expected to result in a slight increase (1%-2%) in real per capita income from 1981 to 1991 (34).

Global interdependence will continue to affect trade balances, monetary values, employment and wages. American competitive strength will be essential to preserving and improving current living standards.

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